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Description

The present invention is concerned with heating elements and, more particularly, with a planar heating element which emits infrared radiation when energised.

Planar heating elements are used as a heat source for heating equipment, cooking appliances, and driers, and are attracting attention as a heat source in applications which require reduced apparatus thickness and uniform heating.

Requirements which can be met using planar heating elements include:

1) superior performance in radiating far infrared rays, and highly efficient use of energy;
2) superior dimensional accuracy during production;
3) low heat capacity;
4) ease of leading out the terminals;
5) ability to uniformly heat objects;
6) high heat resistance and moisture resistance;
7) superior electrical characteristics (insulation resistance and dielectric breakdown strength); and
8) little variation in the resistance value of the heat conductor.

Most conventional planar heating elements consist of a base plate made of mica or other insulating material on which a heating wire is wound; they are poor in transmitting heat to the heating load and, since the heating element is not sealed, there is a problem regarding moisture resistance.

There is another form of planar heating element in which an electrically conductive pattern, formed, for example, of tungsten, is applied as a conductive paste to a non-sintered sheet made, for example, of alumina, a further sheet is stuck thereto and the assembly is sintered. This type of heating element is suitable for applications requiring high heat output, but has drawbacks such as a high heat capacity which results in a long heat-up time and a high sintering temperature which makes it difficult to attach the current supply leads because of melting of the contact material.

There are other forms of planar heating element including one in which an electrically conductive pattern, which may be formed of a thin metal foil, is sandwiched between flexible sheets of insulating material, such as plastics or elastomeric material, paper or textile, including glass or quartz fibre cloth. Elements of this kind are described, for example, in U.S. Patent 3,539,767. Such elements are not intended to operate at high temperatures, their operating temperature being severely restricted by the low heat resistance of the insulating materials used; they also have a limited service life.

According to the present invention, there is provided a planar heating element which comprises a heat-resistant base plate having an electrically insulating layer on at least one surface, and an enamel layer adhered to the insulating layer and in which a heat conducting layer is embedded, characterized in that

(a) the heat-resistant base plate is formed of steel containing, by weight, from 0.001 to 0.1% of carbon, from 0.005 to 0.04% of copper, and from 0.001 to 0.02% of phosphorus, and has a surface coating of nickel of not more than 20 mg/dm^2,

(b) the electrically insulating layer is formed of glass frit having a softening point of from 470 to 650°C, and

(c) the heat connecting layer consists of a preformed metal foil.

The planar heating element of the invention is superior in heat resistance and moisture resistance to those of the prior art and has a low heat capacity. Further, the presence of the enamel layer ensures a high infrared radiation coefficient and the highly efficient use of energy.

For a better understanding of the invention, reference will be made in the following description to the accompanying drawings, in which:

Figure 1 is a cross-sectional view of one embodiment of the planar heating element of the invention;

Figures 2(a) and (b) are plan views of preferred configurations of the heat conducting layer in the planar heating element of the invention;

Figures 3 and 4 are cross-sectional views showing other embodiments of the planar heating element of the invention;

Figure 5 is a detailed cross-sectional view of a portion of Figure 3;

Figure 6 is a graph showing changes in the volume resistivity of various planar heating elements in accordance with the invention as a function of the working temperature; and

Figures 7 and 8 are cross-sectional views of planar heating elements according to further embodiments of the invention.

Figure 1 shows the basic arrangement of the planar heating element of the invention. It comprises a metal base plate 1 which is provided on its surfaces with electrically insulating layers 2a and 2b. Adhered to the layer 2a is an enamel layer 4 in which a planar heat conducting layer 3 is wholly embedded, that is so that the layer 3 is covered by the layer 4.

Preferred configurations of the heat conducting layer 3 are shown in Figures 2(a) and 2(b).

The planar heating element shown in Figure 1 can be made by the following process.

A steel plate to form the base plate 1 is subjected to degreasing, boiling wash, pickling, and boiling wash, and then to nickel plating, boiling wash, and drying. These operations are followed by spraying an enamel slip on to the surfaces of the base plate 1, drying and firing to provide primary enamel insulation layers 2a and 2b. The enamel slip is then sprayed on to enamel layer 2a and a thin metal foil of predetermined pattern serving as the heat conducting layer 3 is laid thereon, this operation being followed by spraying on further enamel slip to cover the metal foil, drying, and firing to form the enamel layer 4. In this way, a planar heating element is obtained in which the metal foil strip is wholly embedded in the enamel layer 4 and is integral with the base plate.

The various components of the planar heating element of the invention will now be described in greater detail.

(1) *Base plate*

The steel plate forming the base plate is made of a low carbon steel having the composition specified above.

Even when a low softening point frit is used to form the insulating layer 4, the temperature of the base plate during enamel firing exceeds 600°C with the result that carbon in the steel plate is liberated as gaseous CO or CO_2 which forms voids in the insulating layer and degrade its insulation properties. Thus, when the carbon content of the steel plate exceeds 0.05% by weight, the proportion of voids in the insulating layer increases sufficiently to degrade its insulation properties. However, in practice it is difficult to remove carbon from steel plate; it is not practical from the standpoint of production and cost to decrease the carbon content to below 0.001%.

Furthermore, the steel plate is subjected to pickling as a pretreatment; when the carbon content is very low,.as described above, the weight loss during pickling is uncontrolled and erratic, which is undesirable from the standpoint of production control and adhesion. The weight loss on pickling is related to the amounts of copper and phosphorus in the steel; it is possible to make the weight loss constant on pickling by adjusting the copper content to from 0.005 to 0.04% by weight and the phosphorus content to from 001 to 0.02% by weight.

As for the conditions for pickling, a weight loss of from 100 to 500 mg/dm^2 is preferred. At less than 100 mg/dm^2, sufficient adhesion cannot be obtained at the firing temperature when using a low-melting point frit. If pickling results in a weight loss of more than 500 mg/dm^2, atomic hydrogen is absorbed in the steel plate during pickling in sufficient amounts to form voids in the insulating layer when the hydrogen is liberated from the steel plate during firing.

Even when the steel plate is pickled as described above, the direct application of the insulating layer to the plate leads to a tendency for the insulating layer to peel off the plate as a result of the heat cycles caused by repeated use of the planar heating element, since the base plate, insulating layer, and heat conducting layer have different thermal expansion coefficients.

To improve the adhesion between the steel plate and the insulating layer, the plate, after pickling, is preferably coated with nickel. The nickel layer is preferably deposited by plating; the coating density is typically not more than 20 mg/dm^2, preferably from 3 to 20 mg/dm^2. If the coating of nickel is insufficient, the bond strength between the insulating layer and the base plate is poor and repeated heat cycling tends to crack the insulating layer and lower its insulation properties. On the other hand, a nickel coating which is too thick causes a problem in that the amount of hydrogen evolved during firing increases.

(2) *Insulating layer and enamel covering layer*

Any suitable high temperature frit may be used to form the enamel of the insulating layers 2a and 2b and the enamel of the covering layer 4. However, to suppress the amounts of carbon dioxide and hydrogen evolved from the base plate and the heat conducting layer during enamel firing, to make it possible to use plates as thin as from 0.3 to 0.6 mm for the base plate without thermal deformation, and to improve dimensional accuracy, the use of frits having a softening point in the range 470 to 650°C (so that the enamel firing temperature is typically in the range 670 to 740°C) is a feature of the invention.

Typical low-softening point frit compositions are shown in Table 1 and particular examples are given in Table 2. The softening points of the frits shown in Table 1 are in the range 510 to 590°C.

Table 1

Frit Composition	Titania opacified frit	Transparent frit
SiO_2	30-36% by weight	31-39% by weight
B_2O_3	15-20 "	13-22 "
Na_2O	7- 9 "	14-22 "
K_2O	7-15 "	1- 5 "
CaO		
Li_2O		
ZnO		13-20 "
Al_2O_3		0- 5 "
ZrO_2	5-10 "	0- 5 "
TiO_2	10-17 "	0- 5 "
P_2O_5	0.5-2.5 "	"
F_2	2-10 "	2-10 "
Linear expansion coefficient ($x10^7$ deg^{-1})	90-110	100-130
Working temperature (°C)	650-720	630-710

Table 2

Frit Composition	1	2
SiO_2	34% by weight	35% by weight
B_2O_3	17 "	17 "
Na_2O	9 "	19 "
K_2O	10 "	2 "
Li_2O		
CaO	1 "	
ZnO		16 "
Al_2O_3		3 "
ZrO_2	8 "	2 "
TiO_2	12 "	
P_2O_5	2 "	
F_2	7 "	6 "
Linear expansion coefficient ($x10^7$ deg^{-1})	100	115
Working temperature (°C)	700	690

Examples of the compositions of typical enamel glazes are given in Table 3.

Examples of the composition of typical enamel glazes are given in Table 3.

Table 3

	a	b	c
Frit (No. 1 in Table 2)	100	100	100
Clay	6	5	5
$NaNO_2$	0.3	0.3	0.3
Al_2O_3	-	20	20
NiO	-	-	7
Pigment	0-3	0-3	0-3
Water	45	60	63

Column "a" in Table 3 refers to a composition used to prepare the usual glazed enamel finish which exhibits a gloss of not less than 80; the amount of pigment added may be varied according to desired colour and colour tone. Column "b" refers to an example in which Al_2O_3 is added in order to improve the electrical insulation of the resulting enamel; other insulation improvers include TiO_2, ZrO_2, BeO, $MgAl_2O_4$, SiO_2, mica, glass fibre, silica fibre, and alumina fibre.

The amount of improver which is added depends on shape, but is preferably from 5 to 50 parts by weight with respect to 100 parts by weight of frit. If the amount is 50 parts by weight or more, adhesion is decreased, while if it is 5 parts by weight or less, the dielectric breakdown strength cannot be increased.

Column "c" refers to an example in which a far infrared radiating material, NiO, is added in order to improve the far infrared radiation characteristic of the enamel. Instead of NiO, such far infrared radiating materials as MnO_x, CO_3O_4, Cu_2O, Cr_2O_3, and Fe_2O_3 may be used. The amount of far infrared radiating material is preferably not more than 50 parts by weight with respect to 100 parts by weight of frit. If such material is used together with an insulation improver, the total amount should not be more than 50 parts by weight with respect to 100 parts by weight of frit; otherwise peeling of the enamel layer takes place, as described above. In addition, the thermal expansion coefficient of the enamel layer is preferably in the range 0.8 to 1.5, the thermal expansion coefficient of the heating element being taken as 1.

(3) *Heat conducting layer*

For the preformed metal foil forming the heat conducting layer, Ni—Cr alloy and stainless steel SUS 430 are particularly suitable, but Fe—Cr alloy, Fe—Cr—Al alloy, and stainless steel SUS 304 may be used. The metal is thinned by cold rolling, hot rolling or supercooling and is then subjected to a surface enlarging treatment, if necessary, in order to improve the adhesion between it and the insulating layer; it is then degreased, washed, and formed into a predetermined pattern by press punching or etching.

The thickness of the heat conducting layer is preferably not more than 120 µm. If it exceeds this value, the matching of thermal expansion coefficients is degraded, the heat capacity of the heat conducting layer is itself increased, or temperature distribution becomes non-uniform.

Table 4 shows the thermal expansion coefficients of materials suitable for making the heat conducting layer of the invention and the thermal expansion coefficients of frits suitable for use therewith. The thermal expansion coefficient of the steel plate used as the base plate was 125×10^7 deg^{-1}.

Table 4

Material of heat conducting layer	Thermal expansion coefficient of heat conducting material ($x10^7$ deg^{-1})	Thermal expansion coefficient of Frit ($x10^7$ deg^{-1})
Ni-Cr alloy	140	80-120
Stainless steel SUS 430	114	80-100
Stainless steel SUS 304	180	120-150
Fe-Cr-Al alloy	115	80-100

The results of further investigations into preferred conditions for the production of the planar heating element of the invention will now be described.

For use as base plates, 0.4 mm thick 50 × 90 mm steel plates containing different amounts of carbon and phosphorus were coated on their opposite surfaces with nickel plating of different thicknesses in accordance with the process described above. Thin metal foils to serve as the heat conducting layers were prepared by punching 50 µm thick stainless steel SUS 430 into one of the patterns shown in Figure 2; this would provide 50 W.

A slip having composition "a" in Table 3 was sprayed onto both sides of each base plate, which was then dried and fired so as to produce enamel layers about 120 µm thick on both sides of the plate. The same slip was then applied to one surface of the plate and a thin metal foil was placed thereon while the slip was still wet. This operation was followed by spraying on more of the slip to cover the metal foil, then drying and firing to produce a heating element. The distance between the base plate and the thin metal was from 140 to 160 µm, and the thickness of the enamel layer covering the thin metal foil was from 250 to 300 µm.

The enamel layers of the planar heating element obtained in the manner described above contain voids due to hydrogen and carbon dioxide evolved from the base plate and decomposition product gas from the sodium nitrite which is present in the slip. The evolution of gas from the sodium nitrite takes place in the initial stage of firing and the gas is dissipated externally as the temperature increases so that it does not tend to remain in the insulating layer. In contrast, the gases evolved from the base plate at high temperatures tend to remain in the insulating layer.

In Table 5, the proportion of voids is indicated by the words, High, Medium, and Low, these terms indicating that the area occupied by the voids in a cross-section of the insulating layer between the base plate and the heating element exceeds 40%, is in the range 20 to 40%, or is less than 20% respectively.

The adhesion of the enamel layer was measured by a method known as the Porcelain Enamel Institute Method (PEI method) in which a recessed deformation is produced in the enamel surface under a predetermined pressure to break the enamel layer and then a bunch of needles from an adherence meter is applied to the test surface and electric current is passed therethrough to measure the percentage exposure of the blank metal and thereby determine the percentage non-exposure of the metal.

The insulation resistance of the enamel layer was measured by applying a voltage of 500 V between the base plate and the heat conducting layer. The results are shown in Table 5.

Table 5

No.	Base plate conditions (% by weight)			Pretreatment conditions (mg/dm^2)		Enamel firing temperature (°C)	Evaluation of enamel covering layer			General evaluation
	Carbon content	Copper content	Phosphorus content	Weight loss on pickling	Amount of nickel plating		Voids	PEI(%)	Insulation (Ω)	
1	0.001	0.02	0.014	270	15	700	Low	90-100	4×10^8	o
2	0.005	"	"	285	15	700	Low	90-100	9×10^8	o
3	0.01	"	"	280	15	700	Low	90-100	5×10^8	o
4	0.05	"	"	275	15	700	Low	90-100	2×10^8	o
5	0.08	"	"	280	15	700	Medium	70-90	8×10^7	Δ
6	0.1	"	"	270	15	700	Medium	65-85	3×10^7	Δ
7	0.2	"	"	275	15	700	High	60-75	4×10^6	x
8	0.02	0.005	"	75	15	700	Low	65-85	6×10^7	Δ
9	0.02	0.01	"	140	15	700	Low	85-100	2×10^8	o
10	0.02	0.02	"	300	15	700	Low	95-100	7×10^8	o
11	0.02	0.04	"	400	15	700	Low	95-100	5×10^8	o

13	0.02	0.02	0.005	45	12	700	Low	55- 75	6×10^7	Δ
14	"	"	0.010	160	15	"	Low	85-100	3×10^8	o
15	"	"	0.015	330	15	"	Low	90-100	5×10^8	o
16	"	"	0.020	470	15	"	Low	85- 95	8×10^7	Δ
17	"	"	0.030	780	18	"	Middle	75- 90	3×10^7	Δ
18	"	"	0.015	75	15	"	Low	30- 65	8×10^7	Δ
19	"	"	"	100	15	"	Low	55- 80	4×10^8	o
20	"	"	"	200	15	"	Low	85- 95	8×10^8	o
21	"	"	"	300	15	"	Low	86-100	5×10^8	o
22	"	"	"	400	15	"	Low	85-100	3×10^8	o
23	"	"	"	500	15	"	Low	85-100	2×10^8	o
24	"	"	"	600	15	"	Middle	85- 95	9×10^6	Δ

25	0.02	0.02	0.015	300	0	700	Low	30- 65	4×10^7	Δ
26	"	"	"	"	5	"	Low	40- 80	8×10^7	Δ
27	"	"	"	"	10	"	Low	85-100	2×10^8	o
28	"	"	"	"	15	"	Low	85-100	4×10^8	o
29	"	"	"	"	20	"	Low	85-100	6×10^8	o
30	"	"	"	"	25	"	Middle	75- 95	3×10^7	Δ
31	"	"	"	"	30	"	High	65- 85	6×10^6	Δ
32	"	"	"	"	15	640	Low	65- 85	8×10^8	Δ
33	"	"	"	"	"	690	Low	90-100	9×10^8	o
34	"	"	"	"	"	740	Low	90-100	4×10^8	o
35	"	"	"	"	"	790	High	95-100	7×10^7	Δ

Figure 3 shows another embodiment of the invention in which insulation layers 6a and 6b are formed on the surfaces of a metal base plate 5, the upper surface of one insulation layer is roughened to the extent that its surface roughness Ra is from 0.1 to 35 μm, an electrical insulation layer 8 whose area is from 20 to 30% more than that of the pattern of the planar heat conducting layer is formed thereon by, for example, spraying using a mask, the planar heat conducting foil 7 is placed on the electrical insulation layer 8, and a cover enamel layer 9 is applied and baked thereon. In this embodiment, the presence of the electrical insulation layer 8 leads to a remakable improvement in the electrical insulation characteristics of the element at medium and high temperatures.

If the embodiment of Figure 3 is modified as shown in Figure 4 by using an electrical insulation layer 10 to cover the entire surface of the heat conducting layer 7, then even higher insulation performance can be obtained. In this embodiment, the heat conducting layer 7 is coated over its entire surface with an electrical insulation layer 10 beforehand. In Figure 4, the parts denoted by the same numerals are the same as those in Figure 3.

The materials used to form the electrical insulation layers 8 or 10 should be heat-resistant, high in volume resistivity, and have a low thermistor B constant; such materials include, for example, alumina, zircon, cordierite, beryllia, magnesia, forsterite, steatite, mullite, boron nitride, glass ceramics, titanium oxide, and porcelain.

The embodiments shown in Figures 1, 3, and 4 may be selected according to the desired working temperature of the planar heating element. For example, the embodiment shown in Figure 1 may be used for medium and low temperatures below 300°C and the embodiments shown in Figures 3 and 4 may be used for high temperatures in the range 300 to 500°C since an additional electrical insulation layer is present.

The electrical insulation layer 8 in the embodiment shown in Figure 3 may be applied by printing or, as indicated earlier, by spraying. In the printing method, a suitable amount of glass frit serving as a binder is added to a high insulation material such as alumina or zircon to provide a printing ink for pattern printing. For the spraying method, it is preferable to use flame spraying, plasma spraying, or water-stabilized plasma spraying. Of these, plasma spraying provides the best electrical insulation.

Figure 5 is a detailed cross-sectional view of a portion of Figure 3 and shows fine particles of electrical insulation material fused together to form the insulation layer 8. The size of the fine particles is preferably in the range 5 to 120 μm, more preferably in the range 30 to 70 μm. As indicated, these particles are fused together to form the layer 8, the porosity of the layer being preferably in the range 5 to 30%. Electrical insulation materials such as alumina and zircon typically have linear thermal expansion coefficients of from 1 to 2 orders of magnitude less than the base plate metal and enamel layer, so that if a less porous spray insulation layer were used, it would be likely to crack by heat cycle and heat shock. Thus the porosity of the layer should be adjusted within the range 5 to 30% according to the linear thermal expansion coefficient and particle size of the material used.

The thickness of the electrical insulation layer 8, which is determined by the object, application, and required degree of electrical insulation, is typically in the range 15 to 200 μm, preferably from 25 to 60 μm, for the purposes of durability and electrical insulation. The insulation layer 8 can also be formed by the hot press method.

Figure 6 shows the relationship between the volume resistivity of planar heating elements having different electrical insulation layers and the reciprocal of the working temperature expressed in absolute temperature T.

In Figure 6, "a" and "b" refer to alumina and zircon insulated base plates, respectively, and are provided for the purposes of comparison, In this Figure, S refers to a planar heating element of the type shown in Figure 1, the glass frit used having the composition shown in Table 6.

Table 6

Component	Parts by weight	Component	Parts by weight
SiO_2	45	Li_2O	2
B_2O_3	15	Al_2O_3	10
Na_2O	15	ZnO	5
K_2O	3	Co_2O_3	0.5

Al in Figure 6 refers to an element of the type shown in Figure 3 using alumina as the electrical insulation material; A2 refers to an element of the type shown in Figure 4 using alumina as the electrical insulation material; B1 refers to an element of the type shown in Figure 3 using zircon as the electrical insulation material; and B2 refers to an element of the type shown in Figure 4 using zircon as the electrical insulation material.

The volume resistivity of each element was calculated using the following equation:

$$\rho v = \frac{A}{d} Rv$$

where

ρv = volume resistivity,
d = thickness of electrical insulation layer,
A = area of heat conducting layer, and
Rv = insulation resistance between the heat conducting layer and the metal base plate.

The insulation resistance was measured by applying a direct current of 500V between the heat conducting layer and the metal base plate.

It can be seen from Figure 6 that the volume resistivity for A1, A2, B1 and B2 is improved by from 1 to 3 orders of magnitude compared with the planar heating element represented by S.

In the examples shown in Figure 6, the thickness of the electrical insulation layer was from 40 to 60 μm, but if the thickness is increased, the volume resistivity can be further improved. Further, if the glass frit used in the examples of Figure 6 is replaced by another glass frit having higher insulation property, it is possible to improve the volume resistivity of the element at medium and high temperatures, *i.e.* in the range 300 to 400°C, by from 2 to 4 orders of magnitude and to decrease the thermistor B constant.

Figure 7 shows an example in which the planar heating element of the invention is embodied in practical form. The numeral 11 denotes a metal base plate formed with an upward projection 12 and covered with an enamel layer 13. The projection 12 is shaped square in order to surround the installation area of a heat conducting foil 14. The numeral 15 denotes the terminals of the heat conducting foil 14. An enamel layer 16 is present in the region surrounded by the projection 12.

Figure 8 shows an example in which a dish-shaped metal base plate 17 is used. In a preferred embodiment, the base plate 17 is 0.5 mm thick, the dimensions of its bottom 18 are 170 × 170 mm, the height of its upright portion is 10 mm, and it has a hole 21 in the wall which serves as a lead terminal port for the passage of the heating lead terminals 20 of a planar heat conducting layer 19.

The base plate 17 is coated with an enamel layer 22 whose surface is roughened by sand blasting and then with an electrical insulation layer 23 having a thickness of from 40 to 60 μm which is a little larger than the pattern of the planar heat conducting foil 19 and which is made of alumina or zircon powder having a particle size of from 30 to 60 μm. The heat conducting foil 19 is placed on the electrical insulation pattern 23 and coated with an enamel layer 24.

The base plate used typically has an effective surface area of 1,000 cm^2 and a thickness of 0.6 mm, while the heat conducting layer is a thin metal foil equivalent to 1.2 kW and formed as shown in Figure 2(b) of 50 μm thick stainless steel, the other conditions being the same as those of No. 33 in Table 5; this gives a planar heating element in accordance with the invention. A fluorine-containing resin dispersion was then sprayed onto the surface of the base plate of the heating element; after drying at 120°C, it was fired at 380°C for 20 minutes to produce a fluorine-containing resin layer having a thickness of from 25 to 30 μm; in this way, a cooking plate A with the resin layer serving as a heating surface was obtained.

Table 7 shows the results of a comparative test between the cooking plate A in accordance with the invention and a commercially available cooking plate B having an effective surface area of about 1,000 cm^2 in which a sheathed heater is embedded in an aluminium die-casting.

Table 7

Time required for heating surface to reach 220°C	Difference between maximum and minimum temperature of heating surface	Power required for cooking 1 kg of meat
A: about 45 seconds	8.5°C	65
B: about 4 minutes	85°C	100

It can be seen that cooking plate A in accordance with the invention is superior to the control example B in heat-up characteristic and in uniform heating. Cooling tests to prepare hot cakes were conducted using cooking plate A and no local unevenness of baking or scorching was observed. After 1,000 such continuous cooking tests, the fluorine-containing resin surface exhibited none of the scorching or discoloration which tended to develope in the area around the heater section of cooking plate B. Thus, the cooking plate according to the invention was found to be capable of uniform long-term cooling. Furthermore, the cooking plate of the invention requires a short preheating time and has a low heat capacity, so that it is very economical and consumes less energy than prior art cooking plates.

The planar heating element of the invention has excellent insulation provided by the enamel layer, can be constructed as a relatively thin structure, can be quickly and uniformly heated, and is capable of far infrared heating, thereby providing an economical heat source. It is therefore suitable for various room heating units, driers, and cooking appliances, and is particularly suitable for infrared foot warmers and panel heaters where infrared heating is essential.

Claims

1. A planar heating element which comprises a heat-resistant base plate (1) having an electrically insulating layer (2) on at least one surface, and an enamel layer (4) adhered to the insulating layer (2) and in which a heat conducting layer (3) is embedded, characterised in that

(a) the heat-resistant base plate (1) is formed of steel containing, by weight, from 0.001 to 0.1% of carbon, from 0.005 to 0.04% of copper, and from 0.001 to 0.02% of phosphorus, and has a surface coating of nickel of not more than 20 mg/dm^2,

(b) the electrically insulating layer (2) is formed of glass frit having a softening point of from 470 to 650°C, and

(c) the heat conducting layer (3) consists of a preformed metal foil.

2. A heating element according to claim 1, in which the enamel layer (4) contains an infrared radiating material.

3. A heating element according to claim 1 or 2, in which an additional electrically insulating layer (8) is interposed between the insulating layer (2) and the heat conducting layer (3).

4. A heating element according to claim 3, in which the additional insulating layer (8) is composed of fused particles.

5. A heating element according to claim 3 or 4, in which the additional insulating layer (8) is applied to the insulating layer (2) by spraying.

6. A heating element according to any of claims 1 to 5, in which the heat-resistant base plate (1) extends beyond the heat conducting layer (3) and forms a projection which surrounds the area defined by said heat conducting layer.

Patentansprüche

1. Planares Heizelement, enthaltend eine hitzebeständige Grundplatte (1) mit einer elektrisch isolierenden Schicht (2) auf wenigstens einer Seite und einer Glasurschicht (4), die an der Isolierschicht (2) haftet und in die eine Wärmeleitschicht (3) eingebettet ist, dadurch gekennzeichnet, daß

(a) die hitzebeständige Grundplatte (1) aus Stahl besteht, der gewichtsmäßig zwischen 0,001 und 0,1% Kohlenstoff, zwischen 0,005 und 0,04% Kupfer und zwischen 0,001 und 0,02% Phosphor enthält und eine Oberflächenbeschichtung aus Nickel von nicht mehr als 20 mg/dm^2 hat,

(b) die elektrisch isolierende Schicht (2) aus einer Glasfritte mit einem Erweichungspunkt zwischen 470 und 650°C besteht, und

(c) die Wärmeleitschicht (3) aus einer vorgeformten Metallfolie besteht.

2. Heizelement nach Anspruch 1, bei dem die Glasurschicht (4) ein infrarotstrahlendes Material enthält.

3. Heizelement nach Anspruch 1 oder 2, bei dem eine zusätzliche elektrisch isolierende Schicht (8) zwischen der Isolierschicht (2) und der Wärmeleitschicht (3) angeordnet ist.

4. Heizelement nach Anspruch 3, bei dem die zusätzliche Isolierschicht (8) aus verschmolzenen Partikeln besteht.

5. Heizelement nach Anspruch 3 oder 4, bei dem die zusätzliche Isolierschicht (8) auf die Isolierschicht (2) durch Sprühen aufgebracht ist.

6. Heizelement nach einem der Ansprüche 1 bis 5, bei dem die hitzebeständige Grundplatte (1) sich über die Wärmeleitschicht (3) hinauserstreckt und einen Vorsprung bildet, der die Fläche umgibt, die von der Wärmeleitschicht definiert wird.

Revendications

1. Un élément de chauffage plan qui comprend une plaque de base (1) thermiquement résistante ayant une couche d'isolation électrique (2) sur l'une au moins de ses surfaces, et une couche d'émail (4) adhérente à la couche d'isolation (2) et dans laquelle est noyée une couche thermoconductrice (3), caractérisé en ce que

(a) la plaque de base thermiquement résistante (1) est formée d'acier contenant en poids de 0,001 à 0,1% de carbone, de 0,005 à 0,04% de cuivre et de 0,001 à 0,2% de phosphore, et a un revêtement de surface de nickel ne dépassant pas 20 mg/dm^2,

(b) la couche d'isolation électrique (2) est formée d'une fritte de verre ayant un point de ramolissement de 470 à 650°C, et

(c) la couche thermoconductrice (3) consiste en une feuille métallique préformée.

2. Un élément de chauffage selon la revendication 1, dans lequel la couche d'émail (4) contient un matériau d'émission d'infrarouge.

3. Un élément de chauffage selon la revendication 1 ou 2, dans lequel une couche d'isolation électrique additionnelle (8) est interposée entre la couche d'isolation (2) et la couche thermoconductrice (3).

4. Un élément de chauffage selon la revendication 3, dans lequel la couche d'isolation additionnelle (8) est composée de particules fondues.

5. Un élément de chauffage selon la revendication 3 ou 4, dans lequel la couche d'isolation additionnelle (8) est appliquée à la couche d'isolation (2) par pulvérisation.

6. Un élément de chauffage selon l'une quelconque des revendications 1 à 5, dans lequel la plaque de base thermorésistante (1) s'étend au-delà de la couche thermoconductrice (3) et forme une saillie qui entoure la surface définie par ladite couche thermoconductrice.

FIG. 1

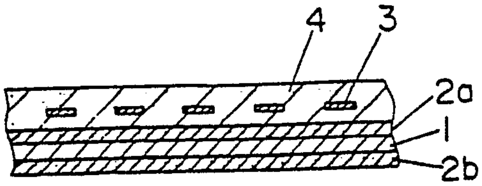
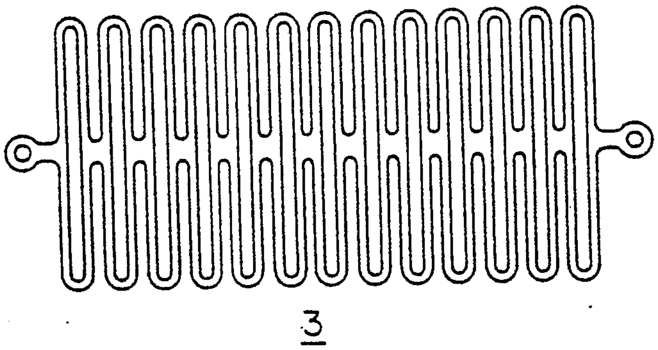


FIG. 2(a)



(b)

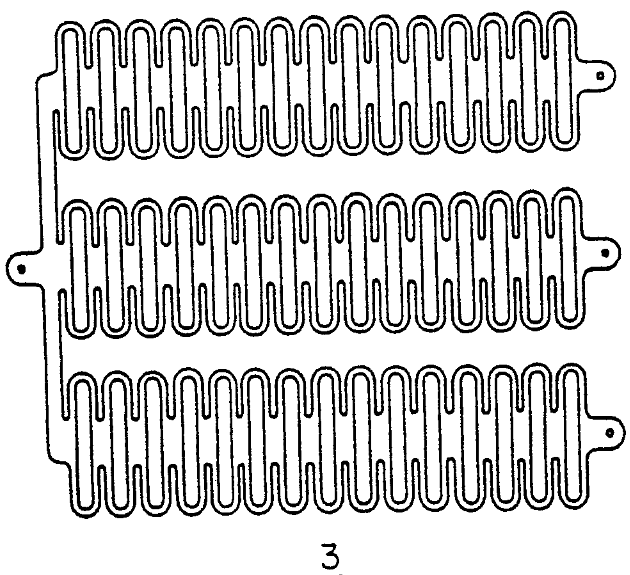


FIG. 3

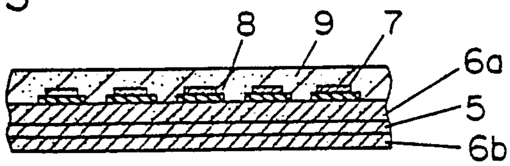


FIG. 4

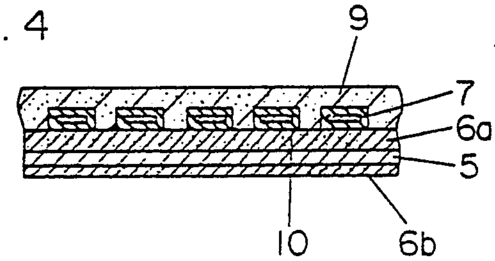


FIG. 5

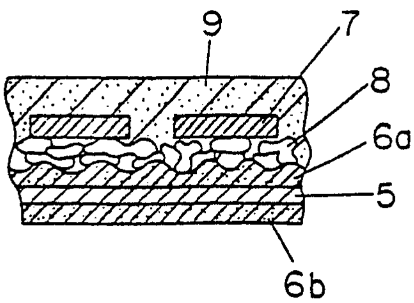


FIG. 6

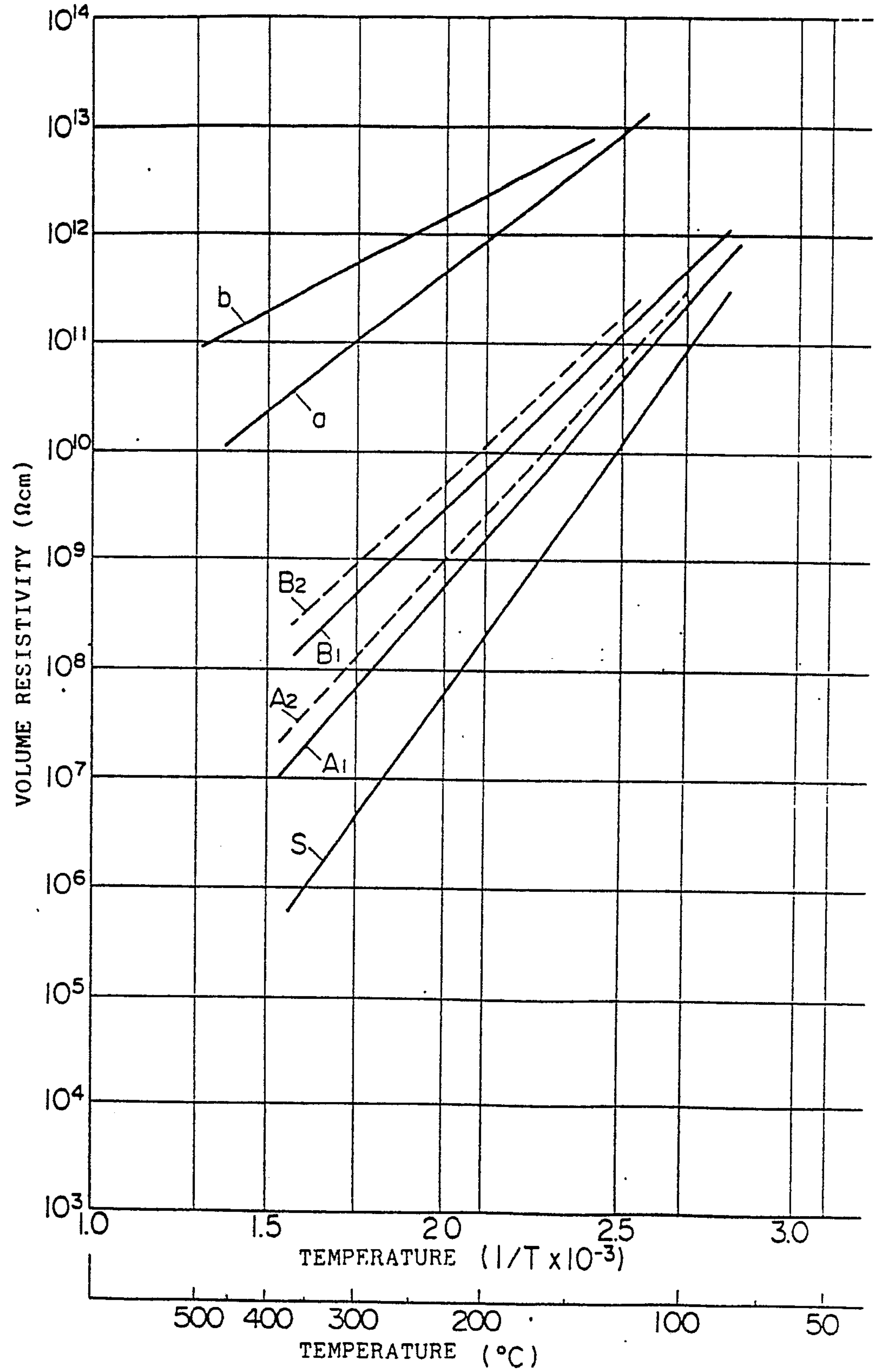

VOLUME RESISTIVITY (Ωcm)
10^14
10^13
10^12
10^11
10^10
10^9
10^8
10^7
10^6
10^5
10^4
10^3
b
a
B2
B1
A2
A1
S
1.0
1.5
2.0
2.5
3.0
TEMPERATURE (1/T x10^-3)
500
400
300
200
100
50
TEMPERATURE (°C)

FIG. 7

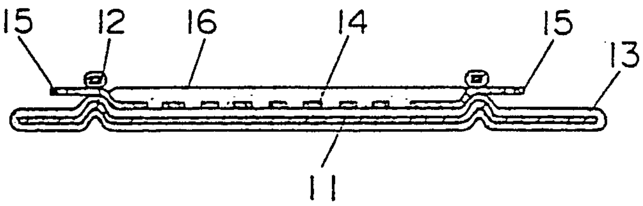


FIG. 8